LOAD DETERMINATION

LOAD DETERMINATION
SECTION 4

CONTENTS

SYMBOLS USED IN THIS SECTION

FS	Factor of Safety	4-4
GWT	Ground Water Table	4-7
T	Tension Load	4-7
SL	Snow Load	4-11
S_K	Snow Load Factor	4-11
ksi	Kips (kilo-pounds) per square inch	4-11
ACI	American Concrete Institute	4-22
AISC	American Institute of Steel Construction	4-22

DISCLAIMER

The information in this manual is provided as a guide to assist you with your design and in writing your own specifications.

Installation conditions, including soil and structure conditions, vary widely from location to location and from point to point on a site.

Independent engineering analysis and consulting state and local building codes and authorities should be conducted prior to any installation to ascertain and verify compliance to relevant rules, regulations and requirements.

Hubbell Power Systems, Inc., shall not be responsible for, or liable to you and/or your customers for the adoption, revision, implementation, use or misuse of this information. Hubbell, Inc., takes great pride and has every confidence in its network of installing contractors and dealers.

Hubbell Power Systems, Inc., does NOT warrant the work of its dealers/installing contractors in the installation of CHANCE® Civil Construction foundation support products.

STRUCTURAL LOADS

TYPES of LOADS

There are generally four common loads that may be resisted by a given foundation element. These are compression, tension, lateral and moment loads. It is anticipated that anyone reading this manual will know the meanings of these loads, but for completeness we will describe them for our purposes here.

A compression load is one that will axially shorten a foundation and is typically considered to act vertically downward. The tension load tends to lengthen a foundation and is often taken to be acting vertically upward. A lateral load is one that acts parallel to the surface of the earth or perpendicular to a vertically installed foundation. The lateral load can also be referred to as a shear load. Moment load tends to bend the foundation about one of its transverse axis. A fifth load is torsion. It tends to twist the foundation about its longitudinal axis. This is a load that is seldom applied except during installation of a helical pile/anchor.

This design manual generally assumes the use of allowable strength design (ASD), i.e., the entire Factor of Safety (FS) is applied to the ultimate capacity of the steel foundation product in the soil to determine a safe (or design) strength. Section 7 of this Design Manual provides the Nominal, LRFD Design, and Allowable Strength of helical pile/anchor. Therefore, the designer can choose to use either limit states or allowable strength design for helical pile/anchor.

DESIGN or WORKING LOAD

The design load or working load is typically considered to be the same load. This is a combination of dead loads and live loads. The dead loads are simply the gravity load of structure, equipment, etc. that will always be there to be resisted by the foundation. The live load takes into account seismic events, wind load, snow load, ice, and occupancy activities. They are transient loads that are dynamic in nature. These loads are sometimes referred to as Unfactored Loads. They do not include any Factor of Safety.

Loads associated with backfill soil should be considered in any type of structural underpinning application. Soil load may be present in foundation lifting or restoration activities and can represent a significant percentage of the overall design load on an individual underpinning element, sometimes approaching as much as 50% of the total design load.

ULTIMATE LOAD

The ultimate load is the combination of the highest dead loads and live loads including safety factors. This load may or may not be the load used for foundation design.

FACTOR of SAFETY

Before a foundation design is complete a Factor of Safety (FS) must be selected and applied. In allowable strength design, the Factor of Safety (FS) is the ratio between the ultimate capacity of the foundation and the design load. A Factor of Safety of 2 is usual but can vary depending on the quality of the information available for the design process and if testing or reliable production control is used. Hubbell Power Systems, Inc. recommends a minimum Factor of Safety of 2 for permanent loading conditions and 1.5 for any temporary loading condition. See page 5-5 for a discussion of Factors of Safety when using ATLAS RESISTANCE® Piers for underpinning (remedial repair) applications.

NOTE: Ultimate load is not the same as ultimate capacity. A foundation has some finite capacity to resist load. The ultimate capacity may be defined as the minimum load at which failure of the foundation is likely to occur, and it can no longer support any additional load.

REVERSING LOADS

Foundation design must allow for the possibility that a load may reverse or change direction. This may not be a frequent occurrence, but when wind changes course or during seismic events, certain loads may change direction. A foundation may undergo tension and compression loads at different times or a reversal in the direction of the applied shear load. The load transfer of couplings is an important part of the design process for reversing loads.

DYNAMIC LOADS

Dynamic or cyclic loads are encountered when supporting certain types of equipment or conditions involving repetitive impact loads. They are also encountered during seismic events and variable wind events. These loads can prove destructive in some soil conditions and inconsequential in others. The designer must take steps to account for these possibilities. Research has shown that multi-helix anchors and piles are better suited to resist dynamic or cyclic loads. Higher factors of safety should be considered when designing for dynamic loads.

CODES and STANDARDS

The minimum load conditions, especially live loads for buildings are usually specified in the governing building codes. There are municipal, state and regional as well as model codes that are proposed for general usage. The designer must adhere to the codes for the project location. Chapter 18 of the IBC 2009 and 2012 contain Code sections for helical piles, as well as sections for general design of deep foundations. Section 4 of ICC-ES ESR-2794 provides guidelines for the design and installation of helical piles.

PRELIMINARY TIEBACK DESIGN GUIDE

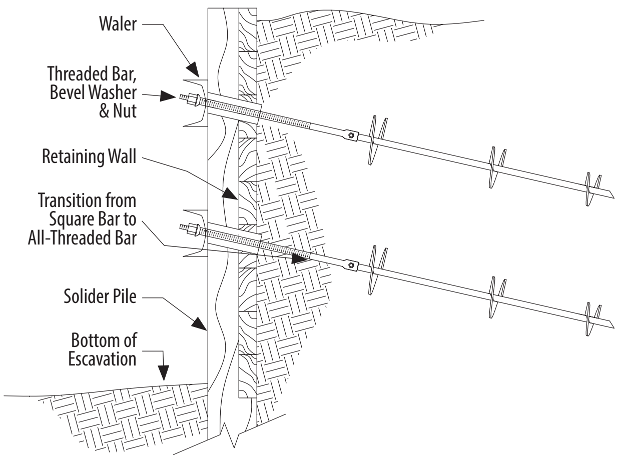
Hubbell Power Systems, Inc. manufactures multi-helix products for use as tiebacks to assist in stabilizing and anchoring structures subjected to lateral loads from earth and water pressure. There are many applications for these tieback products and each application will require:

- An evaluation of the soil characteristics and the lateral earth and water loads on the retaining structure,
- A selection of the appropriate tieback product, including shaft type, helix size(s) and configuration, and
- A determination of the tension load capacity and suitable Factor of Safety.

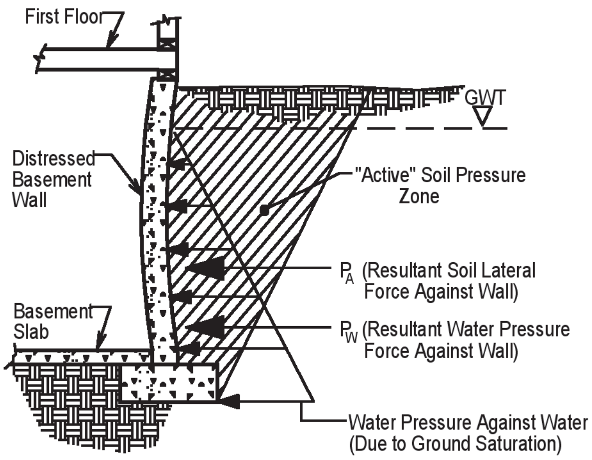
The following preliminary design guide information is intended to assist dealers, installing contractors, and consulting engineers in estimating the required tieback force and placement for the more common tieback applications and to select the appropriate CHANCE® Helical Tieback product. Figure 4-1 illustrates a typical temporary soldier beam and lagging retaining wall utilizing CHANCE® Helical Tiebacks. The commercial uses of CHANCE® Helical Tiebacks include both permanent and temporary sheet pile walls, bulkheads for marine applications, concrete reinforced walls, precast concrete panel walls, etc. They have been used in multi-tier tieback walls to heights of 50’-0.

When using an external waler system consisting of double channels, WF or HP sections, these members shall be positioned relative to the wall face so that their webs are collinear with the tieback tendon. If the waler is not properly oriented with respect to the tieback tendon, then bending moments and shear loads could be introduced into the tieback tendon that could result in a premature failure of the tendon. The tieback tendon is intended to resist only axial loading.

⚠	*It is recommended that a Registered Professional Engineer conduct the design.*

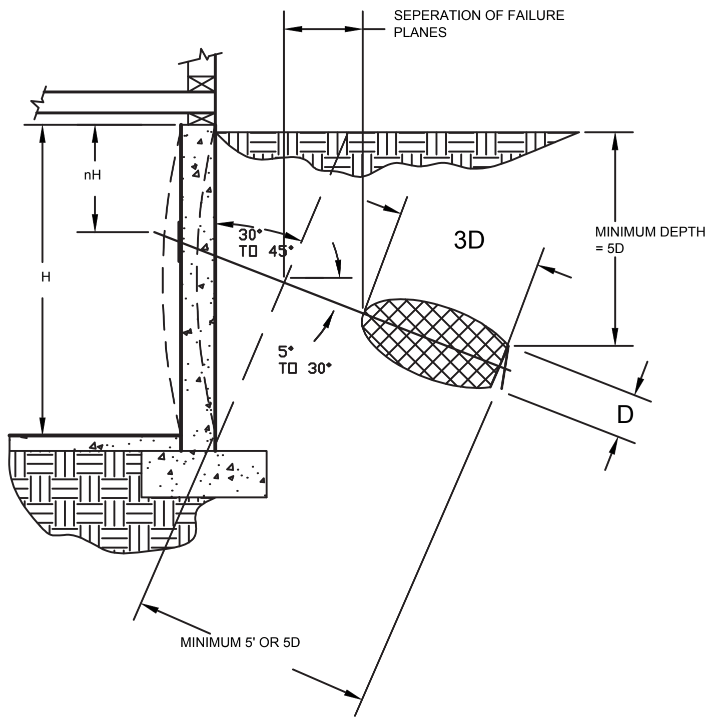


Typical Retaining Wall Tieback Configuration
Figure 4-1



Distressed Basement Wall with “Active” Soil Pressure and Water Pressure Acting Against the Wall
Figure 4-2

LOAD DETERMINATION



Guidelines for Depth and Length for a Typical Installation with Helical Tiebacks
Figure 4-3

TIEBACK DESIGN CONSIDERATIONS

Basement and Retaining Wall Applications

In most regions of the United States, many residential homes have basement walls below grade. Over time, the settling of the ground, plugging of drain tile, extensive rains, plumbing leaks and other environmental factors can cause these basement walls to inwardly bulge, crack, or be subjected to other forms of distress. The CHANCE® Helical Tieback can be an effective repair method for distressed basement walls (See Figure 4-2 and 4-3). There are, however, some general considerations that are important to understand and follow when specifying wall tiebacks.

Active and Passive Pressure Conditions

Figure 4-2 shows a distressed basement wall with the earth pressure "actively" pushing against the wall, as well as water pressure due to the indicated soil saturation condition. Most often it is the combined effect of "active" earth pressure and water pressure that leads to basement wall bulges and cracks. Active earth pressure is defined as the pressure exerted by the earth on a structure that causes movement of the structure away from the soil mass. When a helical tieback is installed and anchored in place, two options are available:

- A portion of the soil is removed, the helical tieback is used to restore the wall toward its original position and the soil is backfilled against the wall, or
- The helical tieback is merely loaded and locked in position with no restoration. In this case, the wall is merely stabilized in its' deflected position.

In either case, the soil will continue to exert an "active" pressure against the wall.

The installed helical tieback anchor develops anchoring resistance capacity through development of "passive" earth pressure against the helical plate. Passive earth pressure is defined as the pressure a structure exerts directly on the earth that causes the structure to move in the direction of the soil mass. Thus it is necessary that the helical tieback anchor be installed properly to ensure the ability to develop full "passive" pressure resistance.

It is very important that the basement wall repair should also include remedial drainage work in order to prevent any future condition of soil saturation and resulting water pressure against the wall and/or take into account the full effect of water pressure against the wall in the tieback design. (See Figure 4-2.)

Location and Placement of Tiebacks

Every tieback wall situation is unique, but there are some aspects that merit extra attention. The placement of the anchor is influenced by the height of the soil backfill against the wall. Figure 4-3 shows this condition and a guide for setting the location and minimum length of installation of the tieback. Experience indicates that the tieback should be located close to the point of maximum wall bulge and/or close to the most severe transverse crack. In cases where walls are constructed of concrete block walls or severe cracking occurred in solid concrete walls, a vertical and/or transverse steel channel (waler) or plate must be used to maintain wall integrity.

For other types of wall distress such as multiple cracking or differential settlement induced cracking, the tieback placement location must be selected on a case by case basis.

Another factor to consider is the height of soil cover over the helical tieback. Figure 4-3 shows the recommended minimum height of soil cover is five times the diameter of the largest helical plate. Finally, the helical anchor must be installed a sufficient distance away from the wall in order that the helical plate(s) can fully develop an anchoring capacity by "passive" pressure as shown in Figure 4-3. This requires the length of installation to be related to the height of soil backfill also shown in Figure 4-3. The top-most or last helix installed must be located a minimum of five times its diameter beyond the assumed "active" failure plane.

Estimating Tieback Load Requirements

Estimating the lateral loads acting against basement walls or retaining walls as exerted by the earth requires knowledge of:

- The soil type and condition,
- The structural dimensions of the retaining structure, and.
- Other geotechnical conditions (e.g. ground water table).

Figures 4-4, 4-5, and 4-6 were prepared for preliminary design assistance for estimating tieback load requirements. Figures 4-5 and 4-6 illustrate cases where no ground water table (GWT) is present at the site. If hydrostatic water pressure is present, the magnitude of this pressure is determined and added to the tieback load requirement from the earth pressure.

In those cases where the soil and subsurface drainage conditions are not known, it should be assumed in the design that water pressure will be present. As a guideline in preparing tieback load requirement estimates, one tieback row (tier) was used for walls of 15 feet of height or less and two tieback rows (tiers) for walls ranging in height from 15 feet to 25 feet. Individual project conditions and design considerations can cause changes in these guidelines.

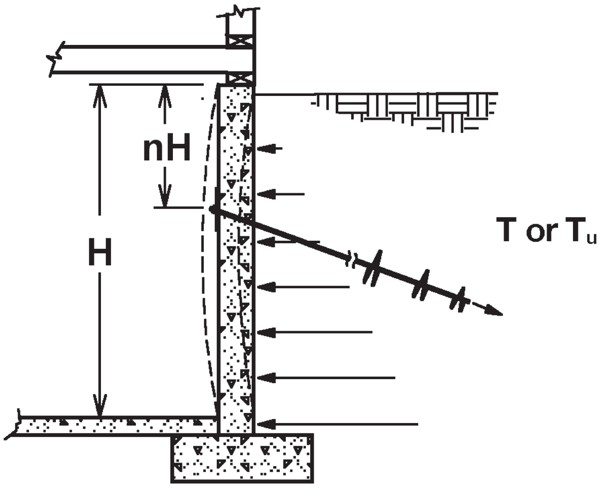
LOAD DETERMINATION

PLACEMENT OF TIEBACK ANCHORS

TYPICAL BASEMENT WALL

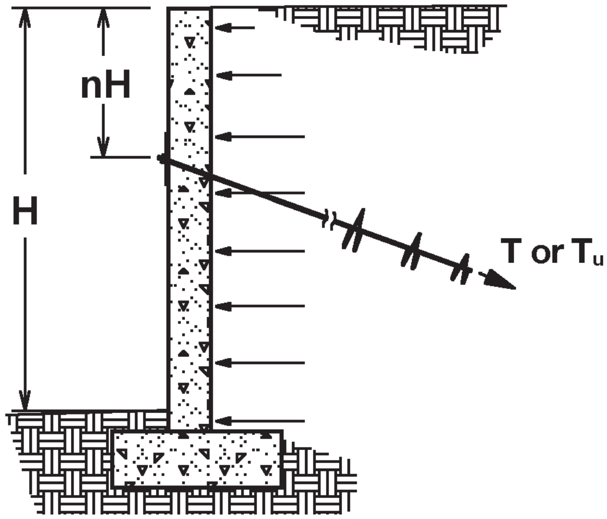
H = Height of backfill
n = Tieback location from top of wall = 0.2 to 0.6
FS = Factor of Safety = 1.5 < FS <2.5
T = Tension load (lb/ft of wall)/cos ø. Assumes tieback provides 80% of lateral support.
T_U = 18 x (H^2) x FS/cos ø (no water pressure present)
T_U = 45 x (H^2) x FS/cos ø (water pressure present)

Note: Top of wall is assumed to be restrained in the lateral direction



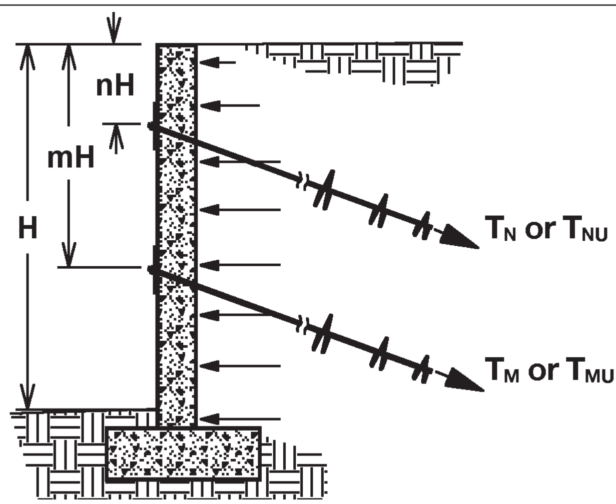
Estimated Tieback Force Required for Basement Applications
Figure 4-4

H = Height of backfill (walls 15 ft or less)
n = Tieback location from top of wall = 0.25 to 0.40
FS = Factor of Safety = 1.5 < FS <2.5
T = Tension Load (lb/ft of wall)/cos ø
T_U = 25 x (H^2) x FS/cos ø
Note: Top of wall is assumed free to translate.



Estimated Tieback Force Required for Retaining Walls 15 Feet High or Less
Figure 4-5

H = Height of backfill (walls 15 to 25 ft)
n = Tieback location from top of wall = 0.20 to 0.30
m = Lower tieback location from top of wall = 0.50 to 0.75
FS = Factor of Safety = 1.5 < FS <2.5
T = Tension Load (lb/ft of wall)/cos ø
T_{NU} = 12 x (H^2) x FS/cos ø
T_{MU} = 18 x (H^2) x FS/cos ø
Note: Top of wall is assumed free to translate.



Estimated Tieback Force Required for Retaining Walls 15 Feet to 25 Feet
Figure 4-6

TECHNICAL DESIGN ASSISTANCE

The engineers at Hubbell Power Systems, Inc. have the knowledge and understand all of the elements of design and installation of CHANCE® Helical Piles/Anchors, Tiebacks, SOIL SCREW® Anchors and ATLAS RESISTANCE® Piers. Hubbell Power Systems, Inc. will prepare a complimentary product selection ("PRELIMINARY DESIGN") on a particular project for use by the engineer of record and our installing contractor or dealer.

If you require engineering assistance in evaluating an application, please contact your CHANCE® Distributor or Certified CHANCE® Installer in your area. These professionals will assist you in collecting the data required to submit the PRELIMINARY DESIGN INITIATION FORM and job specific data. The distributor, installing contractor or dealer will either send Preliminary Design requests to Hubbell Power System, Inc. or will provide the complimentary service themselves.

The PRELIMINARY DESIGN INITIATION FORM may be found on the last page of Section 3 in this manual. Please familiarize yourself with the information that you will need before calling for assistance.

TABLES for ESTIMATING DEAD LINE (DL) and LIVE LINE (LL) LOADS

Tables 4-1 though 4-5 below are provided solely as estimates of the dead and live line loads acting along a perimeter grade beam. It is recommended that a Registered Professional Engineer who is familiar with the site and site specific structural loading conduct the final analysis of the dead and live line loads acting along the perimeter grade beam.

LOAD DETERMINATION

Residential Buildings with Concrete Slab Floors, Table 4-1

BUILDING CONSTRUCTION	BUILDING DIMENSIONS (ft)								
	20′ x 20′	20′ x 30′	20′ x 40′	30′ x 30′	30′ x 45′	30′ x 60′	40′ x 40′	40′ x 60′	40′ x 80′
	ESTIMATED DEAD LOAD at FOUNDATION, DL (lb/ft)								
One Story - Wood/metal/vinyl walls with wood framing on footing.	725	742	753	742	758	768	776	797	810
One Story - Masonry walls with wood framing on footing.	975	992	1003	992	1008	1018	1026	1047	1060
Two Story - Wood/metal/vinyl walls with wood framing on footing.	965	1004	1012	1004	1040	1063	1082	1129	1160
Two Story - First floor masonry, second floor wood/metal.	1215	1254	1280	1254	1290	1313	1332	1379	1410
Two Story - Masonry walls with wood framing on footing.	1465	1504	1530	1504	1540	1563	1582	1629	1660

Residential Buildings with Basements, Table 4-2

BUILDING CONSTRUCTION	BUILDING DIMENSIONS (ft)								
	20′ x 20′	20′ x 30′	20′ x 40′	30′ x 30′	30′ x 45′	30′ x 60′	40′ x 40′	40′ x 60′	40′ x 80′
	ESTIMATED DEAD LOAD at FOUNDATION, DL (lb/ft)								
One Story - Wood/metal/vinyl walls with wood framing on footing.	1060	1092	1114	1092	1121	1140	1156	1195	1220
One Story - Masonry walls with wood framing on footing.	1310	1342	1364	1342	1371	1390	1406	1445	1470
Two Story - Wood/metal/vinyl walls with wood framing on footing.	1300	1354	1390	1354	1403	1435	1462	1528	1570
Two Story - First floor masonry, second floor wood/metal.	1550	1604	1640	1604	1653	1685	1712	1778	1820
Two Story - Masonry walls with wood framing on footing.	1800	1854	1890	1854	1903	1935	1962	2028	2070

Commercial Buildings, Table 4-3

BUILDING CONSTRUCTION	BUILDING DIMENSIONS (ft)								
	20′ x 20′	20′ x 30′	20′ x 40′	30′ x 30′	30′ x 45′	30′ x 60′	40′ x 40′	40′ x 60′	40′ x 80′
	ESTIMATED DEAD LOAD at FOUNDATION, DL (lb/ft)								
One Story - Precast concrete walls on footing with slab floor.	2150	2175	2192	2175	2198	2213	2225	2255	2275
One Story - Precast concrete walls and basement on footing.	3130	3175	3205	3175	3217	3243	3265	3320	3355
Two Story - Precast concrete walls on footing with slab floor.	3425	3475	3508	3475	3521	3550	3611	3636	3675
Two Story - Precast concrete walls and basement on footing.	4490	4560	4607	4560	4624	4665	4700	4786	4840

Estimating Live Loads, Table 4-4

BUILDING CONSTRUCTION	BUILDING DIMENSIONS (ft)								
	20′ x 20′	20′ x 30′	20′ x 40′	30′ x 30′	30′ x 45′	30′ x 60′	40′ x 40′	40′ x 60′	40′ x 80′
	ESTIMATED LIVE LOAD at FOUNDATION, LL (lb/ft)								
One Story - Residential on slab.	N/A								
One Story - Residential on basement. One Story - Residential over crawl space. Two Story - Residential on slab.	250	300	333	300	346	375	400	461	500
Two Story - Residential on basement. Two Story - Residential over crawl space.	500	600	667	600	692	750	800	923	1000
One Story - Commercial on slab.	N/A								
One Story - Commercial on basement. Two Story - Commercial on slab.	450	540	600	540	623	675	720	831	900
Two Story - Commercial on basement.	900	1080	1200	1080	1246	1350	1440	1662	1800

ESTIMATING SNOW LOADS (SL)

The required Snow Load Factor (S_K) can be determined from the locally approved building code. This factor will be given in pounds per square foot. To determine the Snow Load along the perimeter of the structure used the following:

$SL = S_K \times [(w \times L) / 2 \times (w + L)]$

NOTE: w = width of building, L = length of building

TABLES for ESTIMATING FREE SPANS BETWEEN SUPPORTS

Tables 4-6 through 4-9 are provided to help estimate spacing of CHANCE® Helical Piles or ATLAS RESISTANCE® Piers. One must clearly understand that the tables were calculated assuming that the foundation element was fabricated using proper construction techniques, with properly embedded reinforcing bars rated at 60 ksi and with high quality concrete having a 28-day compressive strength of 3,000 psi. After calculating maximum free span using Equation 4-1 below, the results were checked to ensure that beam shear did not yield a shorter maximum span. Keep in mind that poor construction techniques and/or substandard materials will shorten the allowable span. A Factor of Safety must be applied to the calculated maximum CHANCE® Helical Pile or ATLAS RESISTANCE® Pier spacing based upon experience and judgment.

$$L_s = [(F_y \times d \times A_s) / 1.875 \times P)]^{1/2}$$ **Equation 4-1**

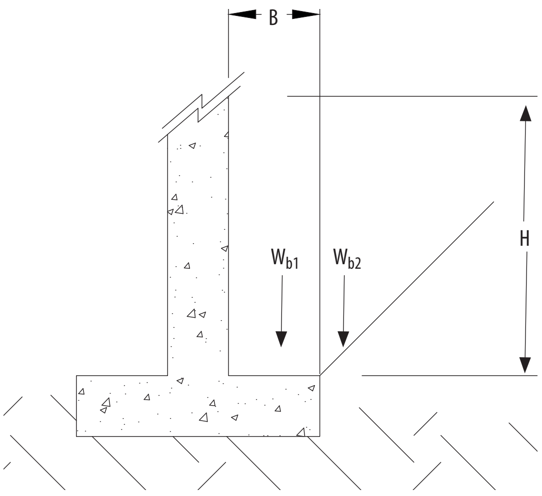
where

- L_s = Maximum footing free span (ft)
- F_y = Rebar yield strength = 24,000 psi
- d = Moment arm distance (in)
- A_s = Cross section area of steel (in^2)
- P = Structural line load (lb/ft)

LOAD DETERMINATION

Estimating Foundation Soil Load (W), Table 4-5

LOAD FROM SOIL OVERBURDEN



Note: W_{b2} may be reduced or may not apply when only stabilizing the structure

FOOTING TOE WIDTH B (in)	HEIGHT OF SOIL OVERBURDEN H (ft)	SOIL TYPE: COHESIVE		SOIL TYPE: GRANULAR	
		W_{b1}	W_{b2}	W_{b1}	W_{b2}
3	2	55	220	75	240
	4	110	880	125	960
	6	165	1980	188	2160
	8	220	3520	250	3840
6	2	110	220	125	240
	4	220	880	250	960
	6	330	1980	375	2160
	8	440	3520	500	3840
9	2	165	220	500	240
	4	330	880	1000	960
	6	495	1980	1500	2160
	8	660	3520	2000	3840
12	2	220	220	250	240
	4	440	880	500	960
	6	660	1980	750	2160
	8	880	3520	1000	3840

Use Table 4-5 for structural underpinning applications.

$$x = \frac{(L_S + w_p/12)}{FS_f}$$

Equation 4-2

where

x	=	Pile/pier spacing
W_p	=	Width of foundation repair bracket (in)
FS_f	=	Factor of Safety based upon field conditions and engineering judgment.

Example: The structure has a 6" thick footing along with an 8" tall stem wall that was cast with the footing. It was reported that building code required a minimum of two #4 reinforcing bars spaced 3" from the bottom and sides of the concrete. The structure is a single story wood frame building with masonry veneer and a 4" concrete slab. The structural load on the perimeter footing was calculated at 1,020 lb/ft plus 250 lb/ft soil overburden.

$$L_S = [(F_y \times d \times A_s) / 1.875 \times P)]^{1/2}$$ **Equation 4-3**

$$= [(24{,}000 \times 11 \times 0.3926) / (1.875 \times 1270)]^{1/2}$$

$$= [43.526]^{1/2}$$

where

L_S = 6.6 ft = maximum free span

d = (6" - 3") + 8" = 11"

A_S = 2 x 0.1963 = 0.3926 in^2

P = 1020 + 250 = 1270 lb/ft

$$x = \frac{(L_S + w_p/12)}{FS_f}$$ **Equation 4-4**

where

w_p = 10" (Atlas AP-2-UFB-3500.165 Pier Bracket) or CHANCE® Underpinning Helical Pile Bracket C1500121

FS_f = 1.2 (Inspection revealed a well built foundation)

$x = \frac{(6.6 + 10/12)}{FS_f} = \frac{7.43 \text{ ft}}{1.2}$

x = 6.19 ft (specify pier spacing at 6 feet on center)

For this project specify the spacing at a maximum 6 feet on center to allow for unexpected defects in the beam or foundation loading, or for possible field adjustments caused by obstructions or utilities.

It is important to keep in mind when one wants to reduce the number of piles/piers on a project, the distances in the tables are for a free span between supports. A supplemental steel footing could be offered to the client, which will effectively expand the distance between piles/piers while maintaining the required free span distance.

If we consider the example above, depending upon the complexity of the architecture, the number of piles/piers could be reduced by perhaps 10% to 15% on the total project by simply installing a 24" long, 3/8" x 6" x 6" supplemental steel beam under the footing.

$$x = \frac{(L_S + L_b/12)}{FS_f}$$ **Equation 4-5**

where

L_b = 24" (supplemental steel beam length)

FS_f = 1.2 (Inspection revealed a well built foundation)

$x = \frac{8.6 \text{ ft}}{1.2}$ = 7.17 ft (pier spacing can be increased to 7 ft on center)

The piles/piers could, if the architecture allows, be spaced on 7-foot centers, while still maintaining the desired 6-foot free span distance.

Tables 4-6 through 4-9 will assist the designer and installer to estimate the maximum free span allowable for some common foundation configurations.

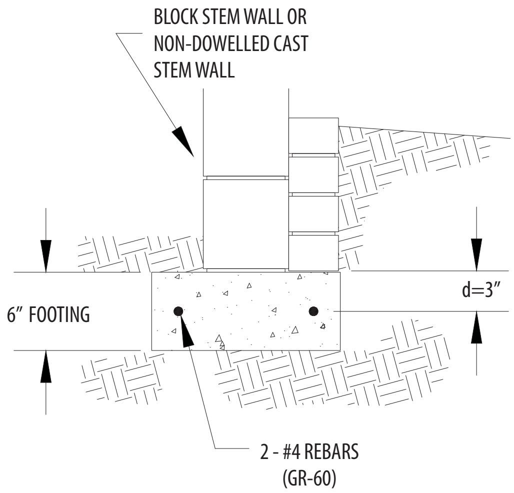


Figure 4-7

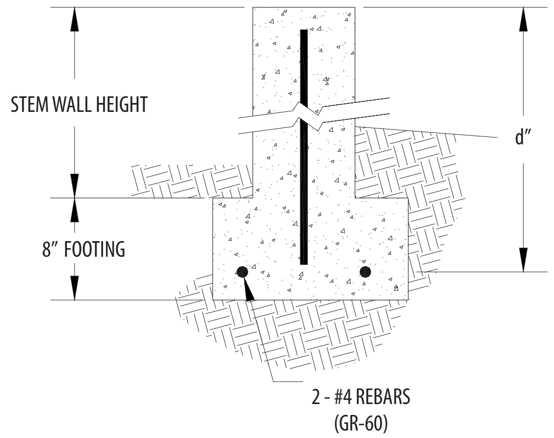


Figure 4-8

WARNING! THE DESIGNER MUST APPLY A FACTOR OF SAFETY TO THE MAXIMUM FREE SPAN WHEN PLANNING THE UNDERPINNING DESIGN SO THAT BEAM FAILURE IS NOT EXPERIENCED.

6″ Thick Reinforced Concrete Spread Footings Maximum Free Spans, Table 4-6

6″ THICK x 16″ SPREAD FOOTING (See Figure 4-7)	BUILDING LINE LOAD (lb/ft.)											
	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000	5,500	6,000	6,500
	MAXIMUM FREE SPAN BETWEEN SUPPORTS											
2 - #4 Rebar (Gr 60): concrete block or cast stem wall (not dowelled) d = 3″	3′-11	3′-2	–	–	–	–	–	–	–	–	–	–
2 - #4 Rebar (Gr 60): 6″ x 12″ tall cast stem wall (dowelled or monolithic) d = 15″	8′-8	7′-1	6′-2	5′-6	5′-0	4′-8	4′-4	4′-1	–	–	–	–
2 - #4 Rebar (Gr 60): 6″ x 18″ tall cast stem wall (dowelled or monolithic) d = 21″	–	8′-5	7′-3	6′-6	5′-11	5′-6	5′-2	4′-10	4′-7	4′-5	4′-2	–
2 - #4 Rebar (Gr 60): 6″ x 24″ tall cast stem wall (dowelled or monolithic) d = 27″	–	–	8′-5	7′-4	6′-9	6′-3	5′-10	5′-6	5′-2	5′-0	4′-9	4′-7
2 - #4 Rebar (Gr 60): 6″ x 48″ tall cast stem wall (dowelled or monolithic) d = 51″	–	–	–	–	–	8′-7	8′-0	7′-7	7′-2	6′-10	6′-6	6′-3

8" Thick Reinforced Concrete Spread Footings Maximum Free Spans, Table 4-7

8" THICK x 16" SPREAD FOOTING (See Figure 4-8)	BUILDING LINE LOAD (lb/ft.)											
	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000	5,500	6,000	6,500	7,000
	MAXIMUM FREE SPAN BETWEEN SUPPORTS											
2 - #4 Rebar (Gr 60): concrete block or cast stem wall (not dowelled) d = 5"	4'-6	3'-9	3'-6	–	–	–	–	–	–	–	–	–
2 - #4 Rebar (Gr 60): 8" x 12" tall cast stem wall (dowelled or monolithic) d = 17"	7'-7	6'-6	5'-10	5'-4	4'-11	4'-7	4'-4	4'-2	3'-11	3'-9	3'-8	3'-5
2 - #4 Rebar (Gr 60): 8" x 18" tall cast stem wall (dowelled or monolithic) d = 23"	–	7'-7	6'-10	6'-2	5'-9	5'-5	5'-1	4'-10	4'-7	4'-5	4'-3	4'-1
2 - #4 Rebar (Gr 60): 8" x 24" tall cast stem wall (dowelled or monolithic) d = 29"	–	8'-6	7'-8	7'-0	6'-5	6'-0	5'-8	5'-5	5'-2	4'-11	4'-9	4'-7
2 - #4 Rebar (Gr 60): 8" x 48" tall cast stem wall (dowelled or monolithic) d = 53"	–	–	–	–	–	8'-2	7'-8	7'-4	7'-0	6'-8	6'-5	6'-2

12" Thick Reinforced Concrete Spread Footings Maximum Free Spans, Table 4-8

12" THICK x 24" SPREAD FOOTING (See Figure 4-9)	BUILDING LINE LOAD (lb/ft.)											
	3,500	4,000	4,500	5,000	5,500	6,000	6,500	7,000	7,500	8,000	8,500	9,000
	MAXIMUM FREE SPAN BETWEEN SUPPORTS											
3 - #5 Rebar (Gr 60): 10" x 12" tall cast stem wall (dowelled or monolithic) d = 21"	8'-4	7'-10	7'-2	7'-0	6'-8	6'-5	6'-2	5'-11	5'-9	5'-7	5'-5	5'-3
3 - #5 Rebar (Gr. 60): 10" x 18" tall cast stem wall (dowelled or monolithic) d = 27"	–	–	8'-5	8'-0	7'-7	7'-3	7'-0	6'-9	6'-6	6'-4	6'-1	5'-11
3 - #5 Rebar (Gr. 60): 10" x 24" tall cast stem wall (dowelled or monolithic) d = 33"	–	–	–	–	–	8'-0	7'-9	7'-5	7'-2	7'-0	6'-9	6'-7

LOAD DETERMINATION

Monolithic Reinforced Concrete Grade Beam Footing Maximum Free Spans, Table 4-9

TURNED DOWN FOUNDATION CONSTRUCTION (See Figure 4-10)	BUILDING LINE LOAD (lb/ft.)											
	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000	5,500	6,000	6,500
	MAXIMUM FREE SPAN BETWEEN SUPPORTS											
12″ high perimeter beam: 2-#4 bottom rebars (Gr 60) d = 9″	6′-9	5′-6	4′-9	4′-3	3′-11	3′-7	–	–	–	–	–	–
20″ high perimeter beam: 2-#5 bottom rebars (Gr 60) d = 17″	–	–	8′-2	7′-5	6′-8	6′-2	5′-9	5′-6	5′-2	4′-11	4′-9	4′-6
24″ high perimeter beam: 2-#5 bottom rebars (Gr 60) d = 21″	–	–	–	8′-1	7′-5	6′-10	6′-5	6′-1	5′-9	5′-6	5′-3	5′-0

WARNING! THE DESIGNER MUST APPLY A FACTOR OF SAFETY TO THE MAXIMUM FREE SPAN WHEN PLANNING THE UNDERPINNING DESIGN SO THAT BEAM FAILURE IS NOT EXPERIENCED.

PRELIMINARY DESIGN GUIDELINES for REINFORCED CONCRETE GRADE BEAMS

Building loads are most commonly transferred to helical piles through concrete grade beams. Figures 4-11 through 4-15 below provide preliminary design guidance for grade beam sizing and steel reinforcement configuration. The grade beam sizing and selection of steel reinforcement tables below include the total line load for live loads on the beam and the dead load of the beam and structure. The 4″ void under the grade beam is for illustration purposes only. The thickness of the void form will depend on site specific conditions. The final design should be conducted and approved by a Registered Professional Engineer.

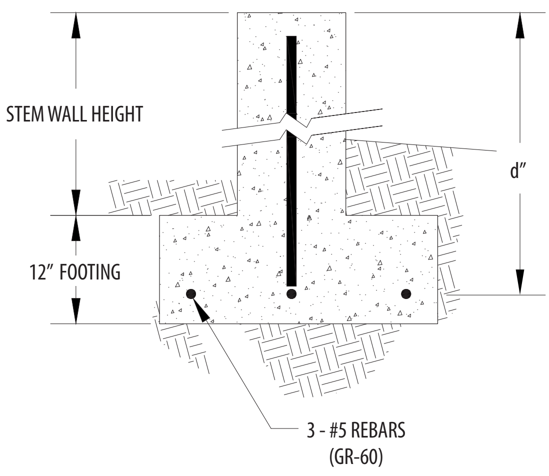


Figure 4-9

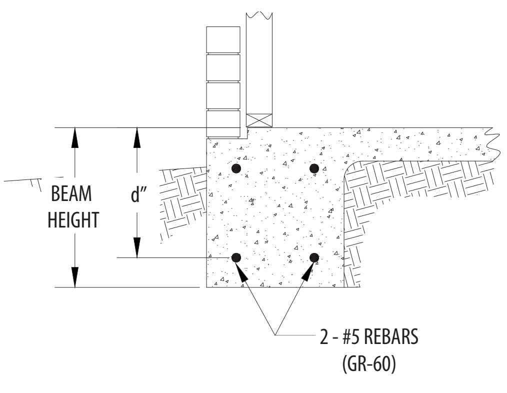
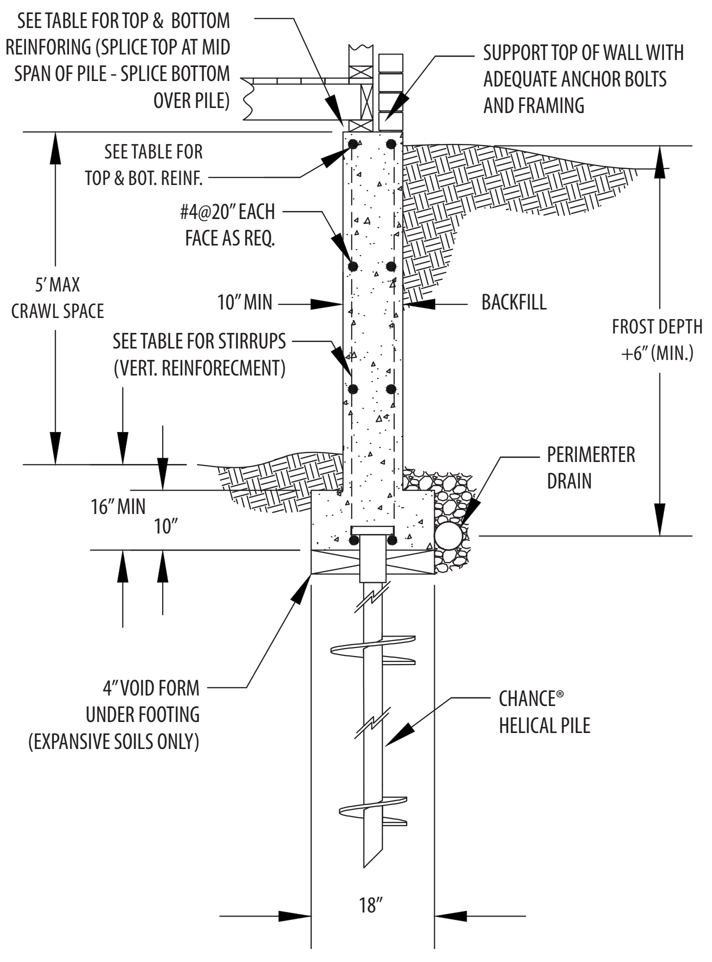
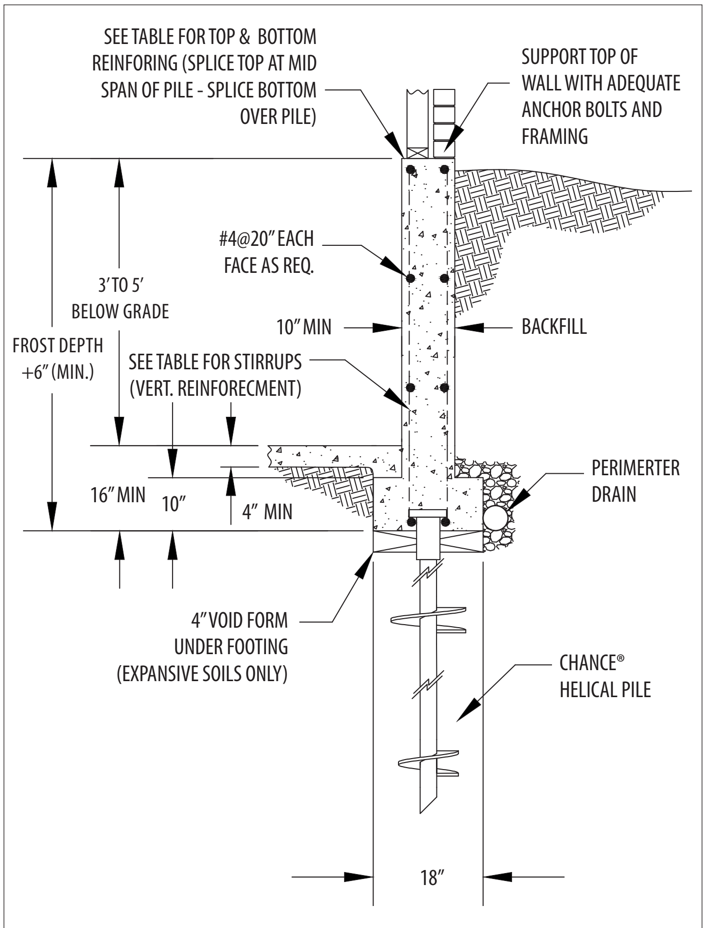


Figure 4-10



Crawl Space Wall Steel Configuration
(See Table 4-10)
Figure 4-11



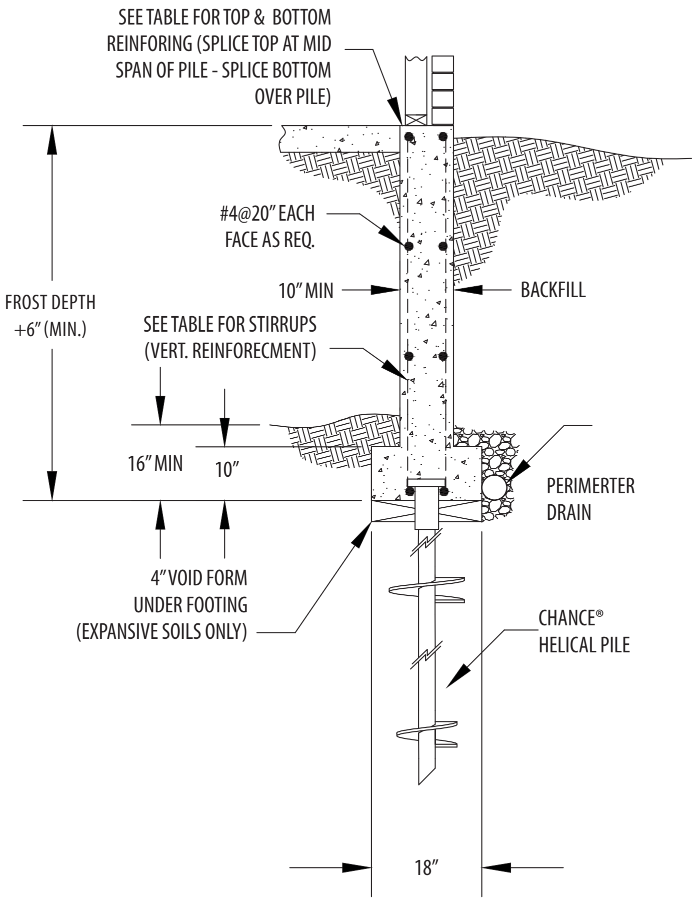
Garden Level Wall Steel Configuration
(See Table 4-11)
Figure 4-12

Crawlspace Wall Reinforcing Steel, Table 4-10

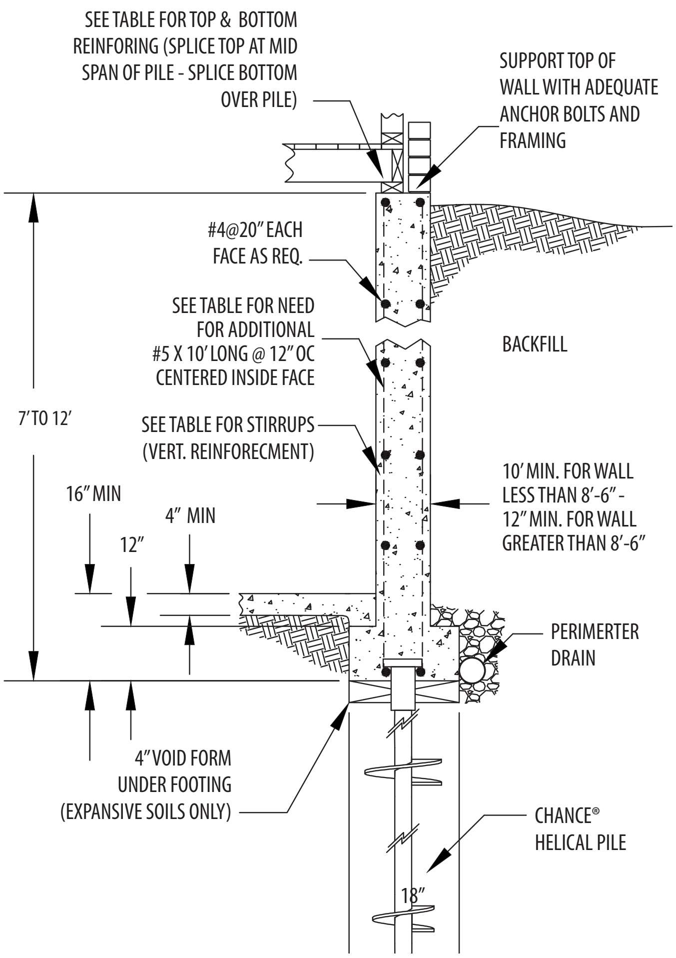
PILE SPACING	WALL HEIGHT	TOTAL FOUNDATION LINE LOAD									
		3,000 (lb/ft)		4,000 (lb/ft)		5,000 (lb/ft)		6,000 (lb/ft)		7,000 (lb/ft)	
		STEEL REINFORCING BARS REQUIRED									
		Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)
8′	3′	2- #5		2- #6		2- #6		2 - #7		2 - #7	
	4′	2- #4	#3 @ 15″	2- #5	#3 @ 15″	2- #6	#3 @ 15″	2 - #6	#3 @ 15″	2 - #7	#3 @ 15″
	5′	2- #4		2- #4		2- #5		2 - #5		2 - #6	
10′	3′	2- #6		2- #7		2- #7		2 - #8		2 - #8	
	4′	2- #5	#3 @ 15″	2- #6	#3 @ 15″	2- #7	#3 @ 15″	2 - #8	#3 @ 15″	2 - #8	#3 @ 15″
	5′	2- #5		2- #5		2- #6		2 - #7		2 - #7	
12′	3′	2- #7		2- #7		2- #8		4 - #6		4 - #7	
	4′	2- #6	#3 @ 15″	2- #7	#3 @ 15″	2- #8	#3 @ 15″	4 - #6	#3 @ 15″	2 - #8	#3 @ 15″
	5′	2- #6		2- #7		2- #7		2 - #8		4 - #6	
15′	3′	2- #8		4- #6		4 - #7		4 - #8	#3 @ 11″	5 - #8	#3 @ 9″
	4′	2- #8	#3 @ 15″	2- #8	#3 @ 15″	4 - #6	#3 @ 15″	4 - #7	#3 @ 15″	4 - #8	#3 @ 15″
	5′	2- #7		2- #8		4 - #7		4 - #7		4 - #7	

Garden Level Wall Reinforcing Steel, Table 4-11

PILE SPACING	WALL HEIGHT	TOTAL FOUNDATION LINE LOAD									
		3,000 (lb/ft)		4,000 (lb/ft)		5,000 (lb/ft)		6,000 (lb/ft)		7,000 (lb/ft)	
		STEEL REINFORCING BARS REQUIRED									
		Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)
8′	3′	2- #5	#3 @ 15″	2- #6	#3 @ 15″	2- #6	#3 @ 15″	2 - #7	#3 @ 15″	2 - #7	#3 @ 15″
	4′	2- #4		2- #5		2- #6		2 - #6		2 - #7	
	5′	2- #4	#3 @ 12″	2- #4	#3 @ 12″	2- #5	#3 @ 12″	2 - #5	#3 @ 12″	2 - #6	#3 @ 12″
10′	3′	2- #6	#3 @ 15″	2- #7	#3 @ 15″	2- #7	#3 @ 15″	2 - #8	#3 @ 15″	2 - #8	#3 @ 15″
	4′	2- #5		2- #6		2- #7		2 - #8		2 - #8	
	5′	2- #5	#3 @ 12″	2- #6	#3 @ 12″	2- #6	#3 @ 12″	2 - #7	#3 @ 12″	2 - #7	#3 @ 12″
12′	3′	2- #7	#3 @ 15″	2- #7	#3 @ 15″	2- #8	#3 @ 15″	4 - #6	#3 @ 15″	4 - #7	#3 @ 15″
	4′	2- #6		2- #7		2- #8		2 - #8		2 - #8	
	5′	2- #6	#3 @ 12″	2- #7	#3 @ 12″	2- #7	#3 @ 12″	2 - #8	#3 @ 12″	4 - #6	#3 @ 12″
15′	3′	2- #8	#3 @ 15″	4- #6	#3 @ 15″	4 - #7	#3 @ 15″	4 - #8	#3 @ 10″	5 - #8	#3 @ 9″
	4′	2- #8		2- #8		4 - #6		4 - #7	#3 @ 15″	4 - #8	#3 @ 15″
	5′	2- #7	#3 @ 12″	2- #8	#3 @ 12″	4 - #7	#3 @ 12″	4 - #7	#3 @ 12″	4 - #7	#3 @ 12″



Grade Frost Wall Steel Configuration
(See Table 4-12)
Figure 4-13



Basement Wall Steel Configuration
(See Table 4-13)
Figure 4-14

Grade Frost Wall Reinforcing Steel, Table 4-12

PILE SPACING	WALL HEIGHT	TOTAL FOUNDATION LINE LOAD									
		3,000 (lb/ft)		4,000 (lb/ft)		5,000 (lb/ft)		6,000 (lb/ft)		7,000 (lb/ft)	
		STEEL REINFORCING BARS REQUIRED									
		Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)	Top & Bottom	Stirrup ("O.C.)
	3'	2- #5		2- #6		2- #6		2 - #7		2 - #7	
8'	4'	2- #4	#3 @ 15"	2- #5	#3 @ 15"	2- #6	#3 @ 15"	2 - #6	#3 @ 15"	2 - #7	#3 @ 15"
	5'	2- #4		2- #4		2- #5		2 - #5		2 - #6	
	3'	2- #6		2- #7		2- #7		2 - #8		2 - #8	
10'	4'	2- #5	#3 @ 15"	2- #6	#3 @ 15"	2- #7	#3 @ 15"	2 - #8	#3 @ 15"	2 - #8	#3 @ 15"
	5'	2- #5		2- #5		2- #6		2 - #7		2 - #7	
	3'	2- #7		2- #7		2- #8		4 - #6		4 - #7	
12'	4'	2- #6	#3 @ 15"	2- #7	#3 @ 15"	2- #8	#3 @ 15"	2 - #8	#3 @ 15"	2 - #8	#3 @ 15"
	5'	2- #6		2- #7		2- #7		2 - #8		4 - #6	
	3'	2- #8		4- #6		4 - #7		4 - #8	#3 @ 12"	4 - #8	#3 @ 9"
15'	4'	2- #8	#3 @ 15"	2- #8	#3 @ 15"	4 - #7	#3 @ 15"	4 - #7	#3 @ 15"	4 - #8	#3 @ 15"
	5'	2- #7		2- #8		4 - #7		4 - #7		4 - #7	

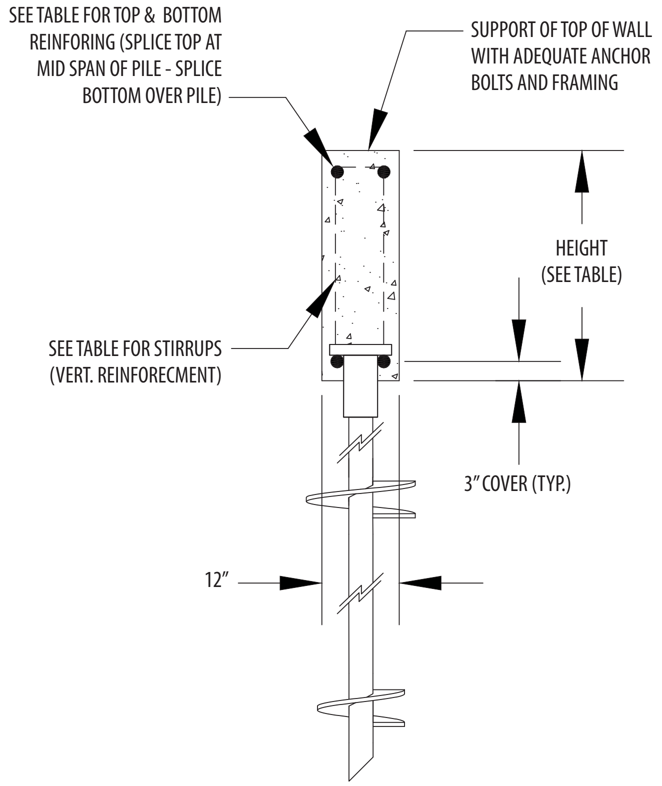
Basement Wall Reinforcing Steel Configuration, Table 4-13

PILE SPACING	WALL HEIGHT	TOTAL FOUNDATION LINE LOAD									
		3,000 (lb/ft)		4,000 (lb/ft)		5,000 (lb/ft)		6,000 (lb/ft)		7,000 (lb/ft)	
		STEEL REINFORCING BARS REQUIRED									
		Top & Bottom	Stirrup (“O.C.)	Top & Bottom	Stirrup (“O.C.)	Top & Bottom	Stirrup (“O.C.)	Top & Bottom	Stirrup (“O.C.)	Top & Bottom	Stirrup (“O.C.)
8′	7′	2- #4	#3 @ 11″	2- #4	#3 @ 11″	2- #4	#3 @ 11″	2 - #5	#3 @ 11″	2 - #5	#3 @ 11″
	8′	2- #4	#3 @ 8″	2- #4	#3 @ 8″	2- #4	#3 @ 8″	2 - #4	#3 @ 8″	2 - #5	#3 @ 8″
	9′	2- #4	#4 @ 12″	2- #4	#4 @ 12″	2- #4	#4 @ 12″	2 - #4	#4 @ 12″	2 - #4	#4 @ 12″
	10′	2- #4	#4 @ 9″	2- #4	#4 @ 9″	2- #4	#4 @ 9″	2 - #4	#4 @ 9″	2 - #4	#4 @ 9″
	11′	2- #4	#4 @ 16″ *	2- #4	#4 @ 16″ *	2- #4	#4 @ 16″ *	2 - #4	#4 @ 16″ *	2 - #4	#4 @ 16″ *
	12′	2- #4	#4 @ 12″ *	2- #4	#4 @ 12″ *	2- #4	#4 @ 12″ *	2 - #4	#4 @ 12″ *	2 - #4	#4 @ 12″ *
10′	7′	2- #4	#3 @ 11″	2- #5	#3 @ 11″	2- #5	#3 @ 11″	2 - #6	#3 @ 11″	2 - #6	#3 @ 11″
	8′	2- #4	#3 @ 8″	2- #4	#3 @ 8″	2- #5	#3 @ 8″	2 - #5	#3 @ 8″	2 - #6	#3 @ 8″
	9′	2- #4	#4 @ 12″	2- #4	#4 @ 12″	2- #5	#4 @ 12″	2 - #5	#4 @ 12″	2 - #6	#4 @ 12″
	10′	2- #4	#4 @ 9″	2- #4	#4 @ 9″	2- #4	#4 @ 9″	2 - #5	#4 @ 9″	2 - #5	#4 @ 9″
	11′	2- #4	#4 @ 16″ *	2- #4	#4 @ 16″ *	2- #4	#4 @ 16″ *	2 - #5	#4 @ 16″ *	2 - #5	#4 @ 16″ *
	12′	2- #4	#4 @ 12″ *	2- #4	#4 @ 12″ *	2- #4	#4 @ 12″ *	2 - #4	#4 @ 12″ *	2 - #5	#4 @ 12″ *
12′	7′	2- #5	#3 @ 11″	2- #6	#3 @ 11″	2- #6	#3 @ 11″	2 - #7	#3 @ 11″	2 - #7	#3 @ 11″
	8′	2- #5	#3 @ 8″	2- #5	#3 @ 8″	2- #6	#3 @ 8″	2 - #6	#3 @ 8″	2 - #7	#3 @ 8″
	9′	2- #4	#4 @ 12″	2- #5	#4 @ 12″	2- #6	#4 @ 12″	2 - #6	#4 @ 12″	2 - #7	#4 @ 12″
	10′	2- #4	#4 @ 9″	2- #5	#4 @ 9″	2- #5	#4 @ 9″	2 - #6	#4 @ 9″	2 - #6	#4 @ 9″
	11′	2- #4	#4 @ 16″ *	2- #5	#4 @ 16″ *	2- #5	#4 @ 16″ *	2 - #6	#4 @ 16″ *	2 - #6	#4 @ 16″ *
	12′	2- #4	#4 @ 12″ *	2- #4	#4 @ 12″ *	2- #5	#4 @ 12″ *	2 - #5	#4 @ 12″ *	2 - #6	#4 @ 12″ *
15′	7′	2- #6	#3 @ 11″	2 - #7	#3 @ 11″	2 - #8	#3 @ 11″	4 - #6	#3 @ 11″	4 - #7	#3 @ 11″
	8′	2- #6	#3 @ 8″	2 - #7	#3 @ 8″	2 - #7	#3 @ 8″	2 - #8	#3 @ 8″	4 - #6	#3 @ 8″
	9′	2- #5	#4 @ 12″	2 - #6	#4 @ 12″	2 - #7	#4 @ 12″	2 - #8	#4 @ 12″	2 - #8	#4 @ 12″
	10′	2- #5	#4 @ 9″	2 - #6	#4 @ 9″	2 - #7	#4 @ 9″	2 - #7	#4 @ 9″	2 - #8	#4 @ 9″
	11′	2- #5	#4 @ 16″ *	2 - #6	#4 @ 16″ *	2 - #6	#4 @ 16″ *	2 - #7	#4 @ 16″ *	2 - #7	#4 @ 16″ *
	12′	2- #5	#4 @ 12″ *	2 - #5	#4 @ 12″ *	2 - #6	#4 @ 12″ *	2 - #7	#4 @ 12″ *	2 - #7	#4 @ 12″ *

* Note: Requires added #5 x 10′ long @ 12″ O.C. bars centered vertically on inside wall face – See Figure 4-14.

Reinforcing Configuration Table, Table 4-14

Pile Spacing	TOTAL FOUNDATION LINE LOAD								
	2,000 (lb/ft)			3,000 (lb/ft)			4,000 (lb/ft)		
	STEEL REINFORCING BARS REQUIRED								
	Height	Top & Bottom	Stirrups (in. O.C.)	Height	Top & Bottom	Stirrups (in. O.C.)	Height	Top & Bottom	Stirrups (in. O.C.)
8′	18″	2 x #5	#3 @ 12″	20″	3 x #5	#3 @ 12″	24″	4 x #5	#3 @ 12″
10′	18″	3 x #5	#3 @ 12″	22″	3 x #5	#3 @ 12″	30″	4 x #5	#3 @ 15″
12′	24″	3 x #5	#3 @ 12″	27″	4 x #5	#3 @ 15″	30″	4 x #5	#3 @ 15″
15′	24″	4 x #5	#3 @ 12″	30″	4 x #5	#3 @ 15″	36″	4 x #6	#3 @ 18″



Grade Beam Design
Figure 4-15

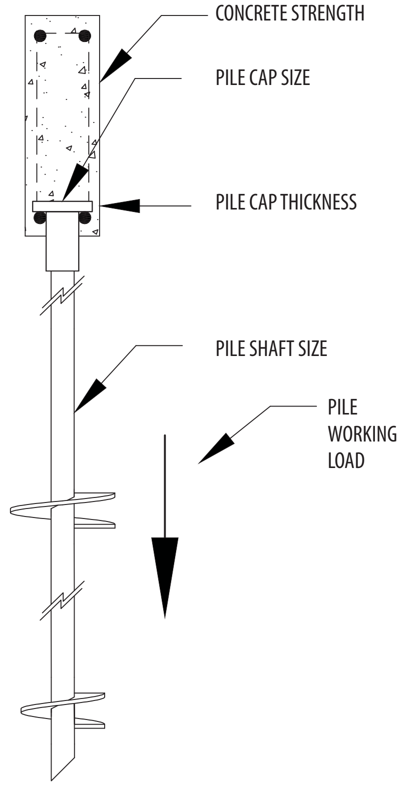
PRELIMINARY DESIGN GUIDELINES for REINFORCED PILE CAPS

Pile cap configurations may be determined from Table 4-15. The table is based upon American Concrete Institute (ACI) criteria for concrete bearing stress from external bearing plates at working loads and from the American Institute of Steel Construction (AISC) criteria for bending stress in the steel plate overhang. Step 1 is based upon a yield-line theory whether bending is across a corner or parallel to an edge.

STEP 1. Select a pile cap plate size from Table 4-15 by looking at the proper row for applicable concrete strength. Locate the lowest value that exceeds the expected pile working load. The proper pile cap plate size is indicated at the bottom of the table.

STEP 2. The pile cap thickness is then determined from the lower portion of Table 4-15. Select the group of rows for the desired pile shaft size. Under the column for the desired pile cap plate size (as determined in Step 1), select the smallest pile cap thickness that exceeds the expected pile working load.

⚠	*It is recommended that a Registered Professional Engineer conduct the design.*



Pile Cap Design
(See Table 4-15)
Figure 4-16

LOAD DETERMINATION

Pile Cap Configuration Table, Table 4-15

STEP 1	PILE CAP PLATE SIZE SELECTOR Limiting Pile Working Loads Controlled by Compressive Strength of Concrete			
Concrete Compressive Strength (psi)	Compressive Working Load on Helical Pile (lb)			
3,000	14,100	32,400	57,600	90,000
3,500	16,800	37,800	67,200	105,000
4,000	19,200	43,200	76,800	120,000
4,500	21,600	48,600	86,400	
5,000	24,000	54,000	96,000	
	RECOMMENDED PILE CAP SIZE			
	4″ x 4″	6″ x 6″	8″ x 8″	10″ x 10″

STEP 2		PILE CAP PLATE SIZE SELECTOR Limiting Pile Working Loads Controlled by Bending Stress in Plate Overhang			
Helical Pile Shaft Series	Pile Cap Thickness	PILE CAP SIZE (From Step 1 above)			
		4″ x 4″	6″ x 6″	8″ x 8″	10″ x 10″
		Compressive Working Load on Helical Pile (lb)			
RS2875.203 RS2875.262	1/4″	23,200	9,780	7,080	5,330
	3/8″	52,200	22,000	15,900	12,000
	1/2″		39,100	28,300	21,300
	3/4″		88,000	63,700	47,900
RS3500.300	1/4″		12,100	8,080	6,250
	3/8″		27,200	18,200	14,100
	1/2″		48,300	32,300	25,000
	3/4″		109,000	72,700	56,300
	1″				100,000
RS4500.337	1/4″		20,000	10,800	8,080
	3/8″		45,000	24,400	18,200
	1/2″		80,000	43,300	32,300
	3/4″			97,500	72,700
SS5 SS150	1/4″	10,000	6,000	5,000	4,000
	3/8″	21,000	12,000	10,000	9,000
	1/2″	40,000	25,000	18,000	16,000
	3/4″	85,000	50,000	40,000	35,000
	1″		90,000	75,000	65,000
SS175	1/4″	14,000	7,000	6,000	5,000
	3/8″	31,000	15,000	11,000	10,000
	1/2″	56,000	27,000	20,000	18,000
	3/4″		60,000	45,000	38,000
	1″		105,000	80,000	70,000
SS200	1/4″	21,000	9,000	6,500	5,500
	3/8″	45,000	18,000	13,000	11,000
	1/2″	82,000	32,000	22,000	19,000
	3/4″		71,000	50,000	42,000
	1″			90,000	75,000